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NON-LIQUID-FUELED VEHICLES IN THE USSR

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TABLE OF CONTENTS

FOREWORD

The purpose of this paper is to present a comprehensive survey of past and present utilization of non-liquid-fueled vehicles in the USSR and of the future potential of such use. It is believed that heretofore there has not been sufficient appreciation of the potential ability of the Soviet economy to effect substantial reductions of its POL requirements by the large-scale utilization of non-liquid-fueled vehicles. This paper is designed as a working aid to assist intelligence analysts engaged in assessing the capabilities and vulnerabilities of the Soviet economy, rather than as a finished intelligence report.

SUMMARY

Soviet use of non-liquid-fueled* vehicles dates from the middle thirties, when it was thought advisable, because of the liquid-fuel shortage, to experiment with local fuels such as wood, charcoal, and peat to power trucks and tractors. Despite the fact that by 1939 experience had forcibly demonstrated that capital and operating costs for vehicles using local fuels were much higher than those for liquid-fueled vehicles, large-scale production began at the end of that year. By the end of 1940, at least four percent of the tractor park (in horse-power) was operating on local fuels; no estimate on the truck park is available. Almost all of these trucks and tractors were of the gas generator type, operating on wood briquettes or charcoal, and limited to areas in which these fuels were available. The 1941 Plan provided that gas generator trucks should constitute approximately 30 percent, and tractors 50 percent, of total production. During the war substantial numbers of trucks and tractors were converted to various local fuels, and as a result large quantities of liquid fuel and the transport facilities necessary to move them from refinery to consumer were released for alternative uses. Consequently, it may be concluded that the higher costs of non-liquid-fueled vehicles were more than offset by a combination of three factors: 1) as a practical matter they worked; 2) they were durable--many are still in use; 3) they brought about considerable savings in liquid fuels and transport costs.

Current use of gas generator vehicles is largely confined to areas and economic organizations which would normally consume large amounts of liquid fuel and which are far removed from the transportation network and from the centers of production of liquid fuel, e.g., the timber industry throughout the USSR, agricultural enterprises in Siberia and probably in the North of the RSFSR. Compressed gas vehicles are used on an increasing but still rather small scale in natural

* For the purposes of this paper the term "non-liquid fuel" or "local fuel" refers to any hard fuel, compressed gas, or refinery by-products. "Liquid fuel" is limited to gasoline, kerosene, diesel fuel, and ligroin. Liquefied gas is to be considered a non-liquid or local fuel.

gas-producing regions, and in the immediate vicinity of metallurgical coke batteries and petroleum refineries throughout the USSR. The current production rate of all types of non-liquid-fueled vehicles is not great; production of trucks does not exceed 15,000 trucks per year while not more than 10,000 gas generator tractors were produced during the Fourth Five-Year Plan. This rate of production is commensurate with the extent of their employment.

Owing to their employment in remote areas, however, non-liquid-fueled trucks and tractors possess an importance to the economy out of all proportion to their numbers. More efficient experimental models of gas generator installations and non-liquid-fueled vehicles have been developed, which may lead to a greatly increased use of local fuels under normal conditions. In addition, the experimental gas generator installations would significantly reduce the cost of conversion in an emergency, i.e., about 650 lbs. of steel are used as compared with about 1,000 lbs. for the older models, and loss in performance would be reduced to a minimum. Mass conversion can be made at a relatively low cost in materials, in a fairly short time, and by utilizing labor and facilities on the local level, e.g., garages, MTS repair shops, and the like. Conversion would not only release large quantities of liquid fuel and rolling stock for alternative uses, but would also, in conjunction with the reserves program, make local areas semi-independent of liquid-fuel supplies for a considerable length of time. This potential of effecting a substantial reduction in the degree of its depending on liquid fuels (POL) represents an important and seldom considered factor in assessing the capabilities and vulnerability of the Soviet economy.

NON-LIQUID-FUELED VEHICLES IN THE USSR

I. INTRODUCTION

[redacted] In using non-liquid-fueled vehicles the Soviets act upon the following considerations: First, there is the high cost of transport (primarily rail) of liquid fuels over the vast area of the Soviet Union. In the late thirties, for example, the average length of haul of liquid fuels was, according to one Soviet writer, 1700 to 1800 kilometers, and occasional cargoes traveled more than 10,000 kilometers to their destination. Consequently, the cost of rail transport alone sometimes exceeded the f.o.b. cost of the fuel by two or three times.[1] This transportation problem was aggravated further by the necessity to haul the fuel from the railhead to the actual point of use, a haul which in lumbering camps often reached 100 to 150 kilometers, requiring the use of 20 to 30 percent of the vehicle pool merely to keep the remainder supplied with POL.[2] Secondly, there is the "necessity for the maximum economy of gasoline, the most strategic /fuel/ product."[3] Thirdly, there is the need to increase greatly the utilization of local fuels, the development of which often lags for lack of consumers.[4] There is one other factor which is not explicitly stated by Soviet writers, although it might be argued that it is implicit in the statement on the need to conserve gasoline as a "strategic" commodity, and that is that the Soviets are by no means oblivious of the savings in gasoline which might be achieved by use of other fuels under war-time conditions when ordinary economic costs count for much less. Nor are they oblivious of the fact that, through the use of other types of fuel, local areas could maintain nearly

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1. Konson, A.S., "Ekonomicheskie VoprosyProektirovaniya Mashin" (Economic Questions of Designing Machinery). Moscow, 1950, p.46.
2. Ibid.
3. BRONSHTEIN, L.A. & NAIDENOV, B.F.,"Tekhniko-Ekonomicheskie Osnovy Premeneniya Mestnykh Vidov Toplivov na Avtotransporte" Economic Bases of the Application of Local Fuels in Autotransport. Technico-Moscow, 1950, p. 153
4. Ibid.

normal levels of activity even though transportation arteries were disrupted for a considerable length of time.

Given this general frame of reference, the widespread use of non-liquid-fueled vehicles poses some interesting problems concerning both the economic significance of this phenomenon and its effect upon the economic and military capabilities of the USSR. Thus it is proper to inquire not only into the present scale of use and geographical distribution of non-liquid-fueled vehicles, but also into the future possibilities of substituting various local fuels for liquid fuel, what the cost of such substitution would be in terms of the materials and labor necessary for equipping and maintaining a considerable part of the Soviet auto and tractor park with various non-liquid fuel installations, and the effect such conversion would have on the capability and general efficiency of the vehicles. Given the answers to these questions, one might proceed to postulate certain general propositions on the effect of the use of local fuels on the strategic capabilities and vulnerabilities of the USSR.

Consequently, it shall be the purpose of this paper to give the best possible answers to the following problems:

a) the politico-economic rationale for substitution of non-liquid-fueled vehicles in USSR;

b) the economic problems of non-liquid-fueled vehicles:

   1. the vehicle--operating costs, capital investment, maintenance, efficiency;

   2. the fuel--technical qualities (weight, caloric content, effect on the engine, necessary equipment for use) and availability (location, volume of production, transportation, alternative uses);

c) significance of non-liquid-fueled vehicles in USSR, and the cost and feasibility of large-scale application and/or conversion.

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II. HISTORICAL BACKGROUND

Pre-1945. The utilization of gas generator and gas cylinder vehicles in the Soviet Union began several years before World War II, and the fuel shortages experienced during the course of the war hastened and increased the size of the program.

Gas cylinder vehicles began to be developed during the years 1936-1939. In the latter year the first natural gas compressor station was built in the city of Melitopol, followed during the next two years by the establishment in the Donbas region of similar stations which handled coke gas. A compressor station built in Moscow during the same period processed illuminating gas, while other stations in Moscow, Gorkij, Baku, Grozny, and Rostov handled various industrial gases.

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Another step in the development of gaseous fuel use was made in the form of a Party Resolution in 1938 by which the foundation was laid for an increased output of gas generator tractors and trucks. [redacted]

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In February 1939 a Party Resolution called for a minimum of 80 thousand gas generator tractors and trucks during the course of the following three years.[5] In November of the same year another decree dealt with improving the operation of the timber industry, where the introduction of gas generators was admittedly the most important task in the field of mechanized timber procurement. The Peoples Commissariat of Timber Industry was ordered to convert 2,300

5. Khranal', A.A. Gazogenerator Na Severe (Gasgenerator in the North, Moscow, 1943, p. 3)

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ChTZ-60 tractors and 1,000 trucks to gas generator operation; Glavlesvlazhprom, 200 tractors and 400 trucks; and the Peoples' Commissariat of Railways, 120 tractors and 400 trucks.[6]

The wider use of gas generators in the USSR was also given special attention at the eighteenth session of the Communist Party. A resolution dealing with the Third Five Year Plan read as follows:

> "Special attention will be given to the production of locomobiles and diesels...and also engines operating on gas. All the vehicles in the timber procurement industry will be converted to gas generator operation, and also a significant part of the tractor park of the agricultural economy and also of the motor transport park."[7]

The extent to which this ambitious program was implemented is not precisely known but the following planned and actual achievements may be cited:

1) In 1939 the GAZ and ZIS factories were to produce 20,000 gas generator trucks; the Khar'kov and Chelyabinsk Tractor Plants were to produce 10,000 gas generator tractors;[8]

2) Of the 131,000 vehicles provided for by the 1941 plan, 40,000 were to be gas generators; of 28,000 tractors, 10,500 were to be gas-generator-powered.

3) According to one source, about 5 percent of the Soviet truck park was composed of gas generators before the war; [9] another Soviet writer lists gas generator tractors as comprising 4 percent of the agricultural tractor park of 1940;[10] many liquid-fuel trucks and tractors were converted to gas

6. Gazogenerator Na Severe, pp. 3-4.
7. Resolution of the XVIII Party Congress, (b), 1939, p. 15.
8. Sovetskaya Arktika (Soviet Arctic) Feb. 1939, p. 49.
9. Gazogenerator Na Severe, p. 49.
10. Venzher, V.P., "Osnovy Voprosy Proizvodstvennoj Deyatel'nosti MTS!" (Basic Questions of Productive Activity in MTS) Moscow, 1949, p. 46.

generators during the war.[11]

By 1941 actual experience and the tests run by various scientific institutes had proved the optimism on the extensive use of local fuels, which is so apparent in the Party Resolutions, to be quite unfounded in terms of comparative costs of operation and production.

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11. An example of the situation during World War II is contained in the <u>Soviet Union Military-Economic Report (Translated from the German Report)</u> dated 25 September 1943 [redacted] 25X1 25X1 This report by the German Signal Intelligence Control Center on the military-economic developments of the Soviet Union (primarily the Caucasus area) in the first half of 1943 and based on Russian domestic radio traffic noted as follows:

"As a result of the German advance in the Caucasus, oil supply ceased and all oil-burning ships were ordered tied up; the crises in the oil situation rising from September 1942 had the result that two basic measures were undertaken to improve the fuel picture. First, conservation measures and a storage system were ordered, and secondly an extensive conversion to other methods of firing was initiated.

* * *

The conversion of trucks and ships was to take into consideration the oil which could be obtained on the spot. There resulted an extensive introduction of gas generators and a changeover to wood firing in plants, shipyards and power stations. Extensive conversion to wood firing was also undertaken in the shipping industry. Trucks and tractors were widely converted to fueling by wood gas. 25X1 [redacted] 25X1 Everyone was urged to make available to all others by interchange of information the technical experience gained in this conversion. For this purpose a conference was called in Moscow in January which was to consider the subject of wood firing aboard ships."

Nevertheless, the 1941 plan provided for a large number of gas generator trucks (approximately 30 percent of total truck production), and tractors (50 percent of total tractor production), a fact which should attest not only to their workability, but also to the importance attached to them as a means of releasing both liquid fuel and transportation facilities for military use.

Postwar. The Fourth Five Year Plan (1946-1950) called for "guaranteeing a wide application of gas generator and gas cylinder trucks in transport, operating on local forms of fuel," and provided further that 70 percent of the trucks and tractors in the Timber Industry should be of the gas generator type. Gas generators and gas cylinder trucks have not, however, become widely used outside the Timber Industry and Agriculture in the Far East. Furthermore, production of both non-liquid-fueled trucks and tractors has not been large in the postwar period.

[redacted] there has been some extension of the use of compressed gas vehicles in the postwar period. In 1946 the entire automobile park of the Drogobych Oblast Automobile Trust in the Ukraine was refitted to operate on gas cylinder fuel, and later the parks of many other automobile trusts of the Ministry of Motor Transport of the Ukrainian SSSR were similarly refitted. Our information on this area is limited, but the following quotation is thought to be fairly indicative of the extent of the program:

> In the Ukraine, vehicles powered by gas flasks are currently operating not only on liquefied gas [butane and propane mixtures] but also on natural compressed, industrial coke, and enriched coke, [synthesized] gases. Since the beginning of 1950, hundreds of gas-flask ZIS-156 and GAZ-51-B trucks have been operating on compressed gas in many cities of the Ukraine. The Gorlovka, Makeyevka, Priazovskoye, and Stalino No. 1 stations, which were destroyed during the war, were rebuilt with a view to increasing their original capacity. Everywhere, except at Azovskoye, an additional compressor was installed. [redacted]

Types of these vehicles currently in operation and/or production are as follows:

Trucks

ZIS-21 - modified version of the ZIS-5 truck; the ZIS-21 is rated at 2 1/2 tons capacity, burns principally wood briquettes or charcoal, and is the only gas generator truck now in production. It is manufactured at the URAL ZIS plant at Miass, near Chelyabinsk.

GAZ-42 - converted version of the GAZ-MM: 1.2 tons capacity, no longer produced.

GAZ-51B-slightly modified version of the 2 1/2 ton GAZ-51 produced at the Gorki Plant - powered by compressed or liquefied gases.

ZIS-156 - compressed gas model of ZIS-150.

Tractors

KhTZT 2G - modified version of the 52 hp. kerosene tractor KHTZ-NATI; produced at the Khar'kov Tractor Plant before World War II.

KT-12 - caterpillar type tractor produced for the Timber Industry; powered by ZIS-21 engine; presently being produced at the Minsk Tractor Plant of the Automobile and Tractor Industry.

SG-65 - converted version of the 65 hp. diesel tractor S-65 produced at the Chelyabinsk Tractor Plant before World War II and for a very short time thereafter.

III. CURRENT PRODUCTION

A. Vehicles

The manufacture of gas generator vehicles of which only two types are presently in production has been concentrated in recent years in two factories in the USSR, the Ural Automobile Plant i/n Stalin at

Miass, near Chelyabinsk, which produces the ZIS-21, and the Minsk Tractor Plant which took over the responsibility for production of the KT-12 timber-skidding tractor from the Kirov Plant in Leningrad about mid-1951. Neither the SG-65 nor the KhTZ-T2G has been produced in the last five years. Some ZIS-150 and GAZ-51 trucks (3 1/2 and 2 1/2 tons respectively) have been converted to compressed gas in addition to a compressed gas truck, the ZIS-156 which is produced at the Moscow ZIS plant.

The volume of production of non-liquid-fueled vehicles is not great. Study of the traffic on the Miass plant indicates a probable rate of production of about 10,000 ZIS-21 trucks per year. The fourth Five Year Plan provided for delivery of 7,500 KT-12 tractors to the Timber Industry, which probably does not include allocations to enterprises subordinate to other Ministries such as Railroad Transportation. However, when we remember that the 1950 annual rate of production envisaged in the Plan was 428,000 trucks and 112,000 tractors, it is apparent that production of gas generator vehicles not only is, but was planned to be, a very small part of the total. As has been noted, however, the conditions peculiar to their primary area of employment increase their significance far beyond their numbers. As for the compressed and liquefied gas vehicles, all evidence indicates that, until very recently at least, they have been produced on a minuscule scale.

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25X1

V. PROBLEMS OF CONVERSION

Conversion of an engine to non-liquid fuels may be accomplished either very simply, if a considerable loss of efficiency can be tolerated, or by extensive modification. The conversion of an engine from liquid fuel to generator gas, without applying special measures, results in a 30-40 percent decrease of power.[13] In order to decrease power losses in the construction of a gas engine, a series of modifications are carried out. The working capacity of the cylinders and the number of revolutions of the crank shaft are increased; the degree of compression is increased, since gas has a higher self-ignition temperature and is less inclined to knock; the pre-heating of gas-air mixtures is eliminated; the dimensions of the intake and exhaust valves are increased in the head of the block; and the period of combustion is shortened by using two spark plugs.[14] If the compression is increased when a diesel or kerosene engine

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13. This is explained by the fact that (1) calorific content of gas-air mixtures (550-600 kal/m^3) is noticeably lower than, for example, that of kerosene-air mixtures (800-820 kal/m^3); (2) the volume of gas admitted into the cylinders of the engine is decreased since there is comparatively greater resistance to the suction of gas air mixtures through all the elements of the gas generator unit; (3) the combustion of gaseous fuels is slower than the combustion of liquid fuels.
14. In the D2G kerosene engine of the KhTZ-T2G tractor, for instance, the intake and exhaust pipes are placed far enough apart so that there is a minimum pre-heating; furthermore the over-all cross-section of the intake pipe is increased; the compression ratio is increased to 8.5 (as against 4.0 in a kerosene engine).

is converted to compressed or liquefied gas, the loss of power is avoided; indeed the engine may deliver more hp. than before conversion.[15] With a gasoline engine, however, a loss of power of about 10 percent is inevitable.

Conversion of any ordinary engine to hard fuels, compressed or liquefied gas, is a relatively simple job which can be accomplished by any local machine shop. If the cylinder head is replaced by one giving higher compression, the loss of power is much less, especially if the engine is being converted to compressed or liquefied gas. Reconversion to gasoline is also simple unless the compression ratio has been substantially increased in order to fully utilize the high-octane rating of compressed and liquefied gases.

The following are among the deleterious effects on the performance of a vehicle when non-liquid fuels are used:

1. As a result of power loss the vehicle must reduce speed to haul the same load; load capacity may be decreased by 20 percent and the ability of the vehicle to carry a full load up inclines is greatly impaired.[16]

2. For vehicles operating on hard fuels, wear on the engine

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15. Korobov, B. A. Traktory, Avtomobili i Sel'skokhozyajstvennye Dvigateli (Tractor, Automobile, and Agricultural Engines). Moscow 1950, p. 120.
16. For example, the comparative drawbar power, in kilograms, of the ligroin-fueled S-65 and the gas-generator SG-65 operating in freshly plowed ground is as follows:

Speed	S-65	SG-65
I	4340	2450
II	2940	1470
III	1640	788
IV	--	--

Korobov, B. A., Ibid p. 391.

is considerably increased [17] and the vehicle must undergo capital repairs more often. [18] The increased wear is attributable both to the corrosive impurities in the generator gas and to the higher operating speed of an engine converted to hard fuels; compressed or liquefied gas, on the contrary, increases length of service up to one and one-half times, as compared with gasoline. [19]

The use of gas generators severely limits the distance traveled before refueling: thus a ZIS-5 truck operating on wood briquettes can travel only about 70 kilometers before refueling; many hard fuels will run the vehicle up to about 120 kilometers before refueling, but this is about the limit. Refueling stations are thus necessary every 60 to 80 kilometers along the route and in the USSR that is quite a problem. The range for vehicles operating on compressed gas is about 120 to 150 kilometers depending upon the number of flasks carried; for liquefied gas it is about the same as for gasoline. [20]

Although oil and grease consumption are listed as being identical for both types, actual practice has proved otherwise. Whether operated

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17. An index to the extent of this wear is furnished by the following figures concerning the amortization allowance per 1000 kilometers for gasoline and gas generator trucks:

Type	Fuel	Rubles
GAZ-MM	gasoline	92
GAZ-14 & 42	gas generator	138
ZIS-5	gasoline	97
ZIS-13 & 21	gas generator	147

Bronshtein, L.A. et al, Avtotransportnyj Spravochnik, (Auto Transport Handbook). Moscow 1950, p. 533.

18. This may be illustrated by a comparison of the norms for distance traveled before capital repair:

Type	Fuel	Kilometers (in thousands)
GAZ-MM	gasoline	60
GAZ-42	gas generator	40
ZIS-5	gasoline	70
ZIS-21	gas generator	50

Bronshtein, L.A. et al Ibid, p. 153.

on a gas generator or on compressed or liquefied gas the engine will use 25 to 30 percent more oil on the average.[21] There have been reports in the Soviet Press that a ZIS-21 engine, unless modified, consumed up to twice the norm of lubricating oil.[22] Modification to alleviate this problem is, however, quite simple.

The f.o.b. cost of the gas generator ZIS-21 is approximately 25 percent higher than its counterpart, the ZIS-5. The comparative costs of tractors are not known. Another cost factor worthy of note is that drivers of vehicles operating on non-liquid fuel receive bonus pay of approximately 30 percent of the base.[23]

Thus it is evident that a vehicle can be converted to non-liquid fuels easily but not so cheaply. Operational costs are considerably higher for vehicles operating on hard fuels than for liquid-fueled vehicles; more metal, more labor and more lubricants are required although less work is done. Compressed or liquefied gases also increase operating cost, principally by reducing the load capacity. [redacted]

TABLE I[25]
(in kopecks)

Type of Fuel	GAZ	ZIS
Gasoline	90.4 / 77.2	57.6 / 98.5
Liquefied Gas	104.6 / 83.2	62.3 / 106.6
Natural Gas	132.5 / 83.5	74.5 / 105.0
Coke Gas	147.2 / 92.1	84.0 / 118.7
Wood Briquettes	156.6 / 107.5	89.0 / 127.0
Charcoal	132.2 / 105.2	89.4 / 127.7
Charcoal Briquettes	137.0 / 109.0	93.7 / 133.9
Peat Coke	154.3 / 105.0	85.3 / 121.3
Peat Briquettes	161.7 / 110.0	90.3 / 123.6
Lignite	153.3 / 104.3	84.0 / 119.5
Anthracite	151.8 / 108.1	80.1 / 123.4
Bituminous Semi-Coke	143.2 / 102.1	77.0 / 118.2

25. Bronshtein, Technico-Economic Questions, pp. 156-157.

TABLE II

Type of Fuel	GAZ	ZIS
Gasoline	100.0	100.0
Wood Briquette	173.5	155.0
Charcoal	146.6	155.2
Charcoal Briquettes	151.8	163.2
Peat Coke	179.0	148.0
Lignite	170.0	146.0
Bituminous Semi-Coke	158.8	133.7
Anthracite	168.8	139.5
Liquefied Gas	116.0	108.5
Natural Gas	147.0	129.6
Coke Gas	160.0	146.0

[redacted]

Table I represents the comparative cost in rubles of GAZ and ZIS trucks operating on various fuels. Included in the Soviet concept of cost are the following factors: wages, fuel - including gasoline used in starting, lubricants, servicing and medium repair, amortization and capital repair, and overhead. The numerator represents the cost in ton-kilometers (the cost of moving one ton a distance of one kilometer), denominator the cost in machine kilometers (the cost of moving the vehicle one kilometer). This table does not, however, allow for the higher initial cost of the non-liquid-fueled vehicle, nor does it allow for the loss in ton kilometers carried per year due to the lower speed and smaller capacity. If these are allowed we get the calculation of "netcost" (sebestoimest') per ton kilometer (gasoline equals 100) as set forth in Table II.

As thus indicated by Table II the gas generator vehicles presently being manufactured are considerably more expensive to operate than their gasoline-fueled counterparts; vehicles operating on natural or liquefied gas are only slightly more expensive. It must be noted however that the fuel prices used in this calculation are "average prices" and the methods employed by the Soviets in arriving at these prices are unknown. Consequently, while they are probably roughly accurate they cannot safely be used as a basis for further detailed analysis. Presumably the price quoted for gasoline, 75 kopecks per liter, contains an "average" freight charge, but the prices for wood briquettes and charcoal, for instance, probably do not include such a charge for the reason that these fuels are simply too costly to transport any distance. While fuel constitutes only about 20 percent of operating costs, it is possible that for a remote logging operation in the Far East, or for a kolkhoz far removed from a railhead, total operating costs - in monetary terms - may actually be cheaper when using a local fuel than when using liquid fuel shipped in from a long distance by rail and then transshipped by truck to the ultimate consumer. Furthermore, use of local fuels not only may save kopecks but also releases rolling stock and trucks for alternate uses.

Consequently, it may be concluded that under present circumstances, viz., the quality of the fuels available and the technological level of the generators and vehicles presently being manufactured, the

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substitution of hard for liquid fuels is not on purely economic considerations justifiable over most of the USSR. There are large areas, however, of the USSR far removed both from the centers of petroleum production and from railheads where such substitution is desirable. [redacted] 25X1

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For compressed and liquefied gases the real cost of operation is only a little more than for liquid fuel; consequently, the use of these fuels may increase in order to release liquid fuels for other uses. In fact, any marked increase in the use of these fuels may provide an index to the intensity of the desire, for whatever ultimate reason, to conserve liquid fuel.

VI. THE FUELS

A. Hard Fuels

Any hard fuel which is to be used on a large scale in gas generator vehicles must meet the following specifications:[26]

1) it must have a considerable range of geographic distribution;

2) it must cost no more than standard gasoline and preferably considerably less;

3) it must have a high "reaction quality";[27]

4) it must have a high calorie content for maximum range of operation;

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26. Bronshtein, p. 13.
27. This is a very important factor meaning, in effect, that the amount of air fed into the combustion chamber of the generator must be small enough so that when the engine must be used at full power, e.g. starting, climbing a steep grade, a considerable increase in the amount of air to speed up the gassification process is possible without simultaneously producing a large amount of inert gases.

5) it must be characterized by low moisture, acid, sulphur, and ash content;

6) weight by volume must be high, and it must be amenable to production in uniform size and quality.

Appendix A contains a detailed discussion of the characteristics of the various hard fuels. Only a general survey will be covered in this portion of the text.

The best hard fuels for gas generators are: wood briquettes, charcoal and charcoal briquettes, lignite and lignite briquettes and coke and semi-coke from lignite and peat, if the ash content of the latter is low.

Wood briquettes, cut to standard size and dried, comprise the standard wood fuel used in gas generators in the USSR and are the most widely used substitute for liquid fuel at the present time. The distribution and quality of Soviet forests make wood a practical gas generator fuel in the following areas: Siberia and the Far East, the Urals, the northern oblasts of the RSFSR, and the Karelo-Finnish SSR. In other areas either forestation is too sparse or the wood is unsuitable for large scale use.[28] Although reliable price data are not available, the evidence at hand leads to the conclusion that wood briquettes can be produced easily and cheaply in the forested areas of the USSR noted above.

Charcoal is probably the second most widely used gas generator fuel in the Soviet Union and is produced widely in the USSR, both by primitive "pile" burning and by special furnaces. A large quantity is produced for and used in the metallurgical industry, and is of necessity of quite high quality. The most advantageous areas for charcoal-fueled vehicles would seem to be in the vicinity of large metallurgical consumers. The amount of charcoal that could be diverted to use in vehicles is problematical and would depend upon the availability of coke as a substitute in the steel furnaces. If modern equipment is used, however, a considerable quantity of relatively high-quality charcoal can be produced at local levels at low cost.[29]

28. Bronshtein, p. 13, 14.
29. Bronshtein, p. 39, 46.

In one form or another lignite (and lignite coke and semi-coke) may offer considerable possibilities as a substitute for liquid fuel. Large deposits of suitable-quality lignite exist in all major industrial areas. Utilization of these local fuels for industry and power generation has been a major goal of the Soviets in the past, and there is evidence that such is still the case. Development for these purposes creates favorable conditions for more widespread uses as a gas generator fuel.

The Soviets have long held out great hopes for the utilization of the USSR's extensive peat deposits for various purposes, but their accomplishments are still far from their grandiose dreams. Very few Soviet peats have a sufficiently low ash content to qualify as an efficient fuel for gas generators. The best peat deposits coincide with the forested areas of the USSR and peat cannot as yet compete with wood briquettes and charcoal.[30] Peat derivatives are also handicapped in that, like bituminous coal and anthracite, they cause a great deal of engine wear. Bituminous and anthracite coals and cokes present serious obstacles to widespread use: serious engine wear, high ash content, heavy and extensive generator apparatus. Simply increasing the quality of the fuel would, however, change the picture considerably.[31] From the point of view of distribution and production, almost all these fuels offer many possibilities for the more widespread use of gas generator vehicles.[32] In considering the possible range of distribution of non-liquid-fueled vehicles, it can hardly be overemphasized that at least 70 percent of the truck park of the USSR is physically juxtaposed to the centers of production and/or consumption of hard fuels, while the Agricultural truck and tractor park is often far removed from a railhead but with a source of local fuel immediately at hand.

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30. Bronshtein, pp. 62-63.
31. See the section on briquetting in Appendix A for the possibilities of better quality hard fuels for gas generator vehicles.
32. Bronshtein, pp. 125-131.

B. Gases

Various kinds of gases are excellent substitutes for liquid fuel. The following is a list of those most suited to this purpose:[33] natural gas, petroleum gas, coke gas, sewage gas and cooking gas. These may be categorized as either compressed gases such as natural or coke gas, which are compressed at very high pressures, or as so-called "liquefied" gases which are a blend of by-product gases from petroleum refining and which liquefy at a pressure of 2 to 3 atmospheres.

Two of the chief limiting factors in the use of compressed gases are the weight of the flasks and the special compressor stations which must be erected. If compressed gas vehicles were to be introduced on a large scale, a considerable investment would be required to construct the compressor stations.[34] Since liquefied gases are under much lower pressure - from 13 to 14 atmospheres - neither the weight of the container nor the compressor installations present such a serious problem. A railway tank car to transport liquefied gas is considerably heavier than one carrying ordinary gasoline, but by no means prohibitively so.

From a supply point of view the possibilities for compressed and liquefied refinery gases are very good. Natural gas exists or is piped into the major industrial areas in the Ukraine and the Donbas, the central region around Moscow, the Baku area, and other areas. Liquefied gas has greater transportation costs than gasoline, but it is an excellent substitute. Since the release of transportation facilities is one of the prime objects of substituting non-liquid fuels, it may be presumed that liquefied gas will be used in the immediate area of the refineries, thus providing more gasoline for transport elsewhere. The really great possibilities in the substitution of gases lie in increasing the supply and efficiency of utilization of coke, cooking, and natural gases - especially the former which is produced in the centers of vehicle concentration. The development of gas-producing plants using lignite in the Urals and Central Asia will greatly facilitate widespread use of compressed gases in those areas.

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33. Bronshtein, p. 135.
34. Details are given at p.47 , Appendix.

VII. FUTURE PROSPECTS FOR NON-LIQUID-FUELED VEHICLES

Although non-liquid-fueled vehicles are quite economical under the special conditions previously described [redacted] there can be no question that the present production models are far too expensive to produce, maintain, and operate over most of the USSR. This is due as noted previously [redacted] to a variety of factors, such as increased wear, loss of capacity, lower performance, increased wages, and the like. On the other hand, even though there is a considerable range in the quality of various local fuels, their abundance and wide geographic distribution in the USSR provide several substitutes for liquid fuels in all of the major industrial centers as well as over considerable portions of the agricultural regions. Consequently, the chief economic limiting factor in the large-scale utilization of local fuels is the technological efficiency of the vehicle. While this is strictly true only under the conditions referred to as the peacetime economy of the USSR, technical efficiency would be quite important if conversion were carried out during war-time, since it is a determinant of the performance, versatility, and operating costs of the vehicle. A comparison of the comparative operating costs set forth in Table II which appears on page 26 with those which appear in Table III, p. 33,will illustrate graphically the economies resulting from a moderate increase in the efficiency of a gas generator truck. It behooves us for two reasons, therefore, to take note of the Soviet experiments on the problem of increasing efficiency: first, they provide some basis for anticipating and evaluating future developments; secondly, the extensive and continuous research program is an index of the importance attached to the application of non-liquid fuels.

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A. Economies of Efficiency and Scale

As has been noted, the economic calculus presented in Table II, p. 26, is based upon now obsolescent trucks, and the same would be true for tractors, designed some 15 years ago. The development of generators and engines which would use non-liquid fuels more efficiently, with less wear, and which would be much lighter, would radically change the situation. For instance, if a non-liquid-fueled truck were developed with the same speed and load-carrying capacity as its liquid-fueled counterpart, the following comparative ton - kilometer costs (in kopecks) would be achieved:

TABLE III

	GAZ	ZIS
Gasoline	100.0	100.0
Wood Briquettes	137.0	129.2
Charcoal Briquettes	140.2	135.3
Peat	131.5	120.8
Lignite	130.6	118.8
Semi-coke	130.6	113.9
Anthracite	135.7	122.7
Natural Gas	107.0	108.5
Coke Gas	115.0	118.5
Liquefied Gas	109.0	109.0

When compared with Table II the reduction in cost is quite impressive, and it should be noted that in all these calculations the models based on the ZIS-5 truck are considerably cheaper to operate than those built around the smaller older GAZ-MM or GAZ-AA. Presumably, therefore, the more modern and larger ZIS-150 and GAZ-51 models would further reduce the cost gap between liquid and non-liquid fuels. It is important to note that in the table of comparative ton - kilometer operating costs given above, the money cost of operating the ZIS truck on many non-liquid fuels is a little less than the cost of operating the GAZ-MM on gasoline. Although the available evidence is too scanty for a final conclusion, it is very likely that the ton - kilometer cost of operating a ZIS-150 on some non-liquid fuels is less than for operating the ZIS-5 on gasoline.

B. New Generators and Vehicles

The ZIS-352,[35] a much improved version of the ZIS-21 truck (gas generator), was tested in the winter of 1949-50 and produced very interesting results. The weight of the gas generator has been reduced and the horsepower increased so that performance is nearly equal to the ZIS-5 on gasoline; engine wear is only slightly less than normal due to a better filter which removes the impurities. Another new type truck developed was the GAZ-51-B,[36] a model designed for operation on compressed gas. Performance of this model is actually superior to the gasoline model.

Three recent developments in gas generator tractors are of considerable interest. One is a new gas generator for the KT-12 tractor which has proved quite successful in operation. The chief advantages of this generator are: it uses green firewood which releases one laborer

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35. Compared with the previous type, the new unit has the following advantages: (1) less weight (355 kg. to 518 kg.); (2) ability to operate on green firewood (this increases fuel consumption about 80 percent with no further loss of hp.; furthermore, green firewood costs only about 25 percent as much as wood briquettes with 20 percent moisture content); (3) a special adjustment for starting under winter conditions; (4) a more durable gasification chamber that is easier to repair; (5) better dust filter, generally simplified design.
36. The most important features of this new truck are: (1) an improved flask of lighter weight which contains enough fuel to run 235 kilometers, consequently, only one or two instead of six flasks need be mounted; (2) an increase of compression from 6.2 to 8.6, as a consequence, the engine develops 76 hp. on compressed gas compared to 70-72 hp. for the standard engine operating on gasoline, and the 55-60 hp. for the standard engine converted to compressed gas. As a result of these improvements this model can operate as efficiently on natural and, even more important, on enriched coke, cooking, or sewage gas, as the standard truck operates on gasoline. Repair costs will doubtless be considerably less; the only higher cost items are the cost of the flask and the driver's bonus.

per tractor day as compared with the old model which required dried briquettes; as much work is accomplished and the new generator lasts longer.[37] The second new development is a gas generator model of the caterpillar diesel tractor S-80, denominated the SGD-80. Judging from the meager reports so far available the new tractor has a "gas engine" which means a higher compression ratio and possibly other changes which permit more efficient use of generator gas. According to press reports, this model has undergone successful field tests.[38]

The single most important development in experimental non-liquid-fueled vehicles is a gas generator model of the 54-hp agricultural diesel caterpillar tractor (the DT-54) - the basic agricultural tractor of the USSR. There are two variations of this model (GB-58 and GT-58) with slightly different types of gas generators depending upon the type of fuel to be burned. These models will burn a variety of fuels including wood briquettes, charcoal, anthracite, lignite, peat, coke and semi-cokes.[39] There is no power loss with these generators, while a much improved filter virtually eliminates the excess engine wear usually attendant upon the use of most of these fuels. Performance (i.e., field work done in a given period) is substantially the same as for the diesel model.[40]

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37. Lesnaya Promyshlennost', 29 May 1952.
38. Lesnaya Promyshlennost', February 1952; Leninskoe Znamya, 29 September 1951.
39. Velichkin, L.M., Iudyshkin, V.G., Artamnov, M.R., "Gas Generator Tractors GB and GT-58," Avtomobil'naya Promyshlennost' No. 7, 1951
40. By increasing the compression ratio to 8.5 and the revolutions of the crankshaft from 1300 to 1400 per minute there has been no loss in engine horsepower; depending upon the type of fuel, engine horsepower ranges from 50 to 57 as compared to 54 for the diesel model. To compensate for the lower "reactive quality" of these fuels the gear ration in the final drive has been increased from 2.56 to 2.93 comparable drawbar power (in kilograms) on stubble is as follows:

Gear	DT-54	GB & GT-58
1st	2919	2810
2nd	2160	2070
3rd	1783	1700
4th	1486	1395
5th	1003	920

Ibid.

This is the first time that the Soviets have had a really practical gas generator which would burn most of these fuels.[41] One serious deficiency remains, however, which detracts from their usefulness, namely the tractor must be refueled every 1 to 1.5 hours when operating on wood briquettes, (every 2.5 hours on semi-coke, and every 3 hours when using peat briquettes).[42] Consequently there is not only a considerable amount of effort involved in keeping the tractors in the field supplied with fuel, but also a significant loss of working time during the refueling stops. Under Soviet conditions where plowing and harvesting must be done in a relatively short time, this can be a serious matter. On the other hand, fuel costs are quite low; for example, the cost of charcoal burned in plowing one hectare of grain stubble is only 4.65 rubles.[43]

In addition to these vehicles, the Soviets have produced experimental models of a steam tractor and a steam truck. While detailed information on these vehicles is still a little scarce, the Soviets claim that both the truck and the tractor are more efficient than the gas generator models, and indeed approach liquid-fueled vehicles in operating costs; the original cost, however, is quite high.[44] One of the great advantages of steam vehicles is that they are not limited by the chemical qualities of the fuel; the only limitations are the calorie value per kilogram, and the weight by volume, both of which radically affect the range of the vehicle with one load of fuel. Obviously, steam-powered vehicles would offer great possibilities if operated on coal, lignite, peat, and other low-cost local fuels with chemical properties that seriously inhibit their use in gas generators.

C. Fuels

Some developments in fuels also are interesting. As has been noted, the Soviets have been devoting a good deal of attention to briquetting various hard fuels. The Ukrainian Scientific Research Institute of Local Fuels has produced a briquette from anthracite waste which contains only small amounts of sulphuric acids and volatile substances. Furthermore,

according to press reports the Soviets plan to build a very large number of gas-producing plants using peat and brown coal. Should this program be carried out, the possibilities for use of compressed gas vehicles would greatly increase.

The importance of these developments is quite evident both in terms of substitution under "normal" conditions for more purely economic reasons, and in terms of the impact of conversion under wartime conditions. In the first place, the greater technological efficiency of the vehicle increases the geographical area in which non-liquid-fueled vehicles can "compete" with liquid-fueled vehicles on the basis of operating costs. However, the Soviets may use criteria other than comparative costs in making a decision of the "profitable" scale of substitution, namely, they may well take into account the secondary effects on capital investment. Thus, if current truck production would add 1,000,000 tons to the yearly gasoline requirements of the USSR, the amount of capital necessary to increase the production of lignite or wood briquettes by 3,860,000 tons (the equivalent of 1,000,000 tons of gasoline for the older model generators) and steel by 75,000 tons might be much less than the amount of capital necessary to produce and transport the additional gasoline. Under Soviet conditions this would make the substitution desirable. Furthermore, a similar type of substitution has taken place in the USSR since 1937. One of the primary reasons for the switch to caterpillar tractors, despite the greatly increased cost in steel, labor and capital equipment, was to save fuel. Finally the Soviets changed to the heavier diesel tractor in the beginning of 1950 for the same reason: 30 percent less fuel for the same amount of work as compared to the kerosene model.

Secondly, technological efficiency is extremely important in assessing the impact of the substitution of local fuels in wartime. Since what occurs is the substitution of one group of scarce commodities and factors, local fuel, metal, labor, for a scarcer group, petroleum products, transport facilities, labor, anything that reduces the real cost of substitution is of great value to the economy. Some notion of this real cost may be gained from the following example. Let us assume that the Soviets wish to save 1,000,000 tons of diesel fuel, and the transport facilities necessary to move it.

Cost of Conversion

metal (mostly medium grade steel)	20 to 25,000 tons
labor	n.a.

Operating Costs

fuel	2,200,000 tons of charcoal 3,000,000 " " wood briquettes or lignite
labor	increase of about 25 percent (physical indices not available)
spare parts	increase of about 15 percent (physical indices not available)

Finally, in any estimated future use of non-liquid fuels it must be remembered that the yearly increment to consumption as a result of current production of trucks and tractors alone is in excess of 1,500,000 of gasoline for the former, and at least 1,000,000 tons of diesel fuel for the latter. A very rapid increase in petroleum production which was envisaged in the fifth Five Year Plan is therefore a necessity. However, local fuels could serve as a very substantial cushion should not this rapid increase be achieved.

In summary, recent experimental models have greatly enhanced the prospects for further utilization of local fuels under "normal" conditions, and have reduced the real cost of large-scale conversion in regard to both materials and performance. Owing to secondary investment effects, and probably to eventually increased production costs of liquid fuels, large-scale utilization of local fuels for internal combustion engines may in the future become increasingly desirable, and even necessary, in the USSR.

VIII. CONCLUSIONS

The influence of non-liquid-fueled vehicles upon the strategic capabilities of the USSR may be stated in the following terms:

(1) Although the present non-liquid fuel truck and tractor park of the USSR is not large, and although present rate of production is not high, these vehicles are employed in areas far removed from the principal transportation nets and/or from major production centers or liquid fuels. Consequently their importance to the economy is far out of proportion to their actual numbers.

(2) Local fuels can be used as an alternative if a continuation of the current high level of truck and tractor production places an undue burden upon the petroleum industry;

(3) Recent technical advances give rise to the possibility that, when due allowance is made for the secondary effects on capital investment, local fuels may become more economical than liquid fuels over a much greater geographical area than at present, thus contributing to the efficiency of the economy as a whole;

(4) Under wartime conditions the large-scale substitution of non-liquid fuels is quite practical and would

(a) release large quantities of fuel for military use without seriously inhibiting a high level of industrial and agricultural production;

(b) ease the burden on transportation facilities, especially the railroads;

(c) increase the self-sufficiency of local areas and add greatly to the efficiency of the already large reserve program in enabling a region such as the Far East to operate at a high level of economic and military activity even if normal communications facilities were seriously disrupted.

[redacted]

APPENDIX

1. Wood Briquettes

Some advantages of wood briquettes are: (a) low cinder content, (b) low sulphur content, (c) ease of manufacture and consequent low production cost if the drying problem can be conveniently solved.[45] Some of the disadvantages are: (a) moisture content of green wood is at least 50 percent and must be reduced to 20 percent for efficient use; drying can be done in open air or in sheds south of the 57th parallel, but north of that line some mechanical aid is needed;[46] when stored, briquettes will re-absorb a considerable amount of moisture under certain weather conditions; (b) wood has a high ash content requiring frequent cleaning of the generator installation and consequent loss of time, and is very bulky to transport, considering that kilogram for kilogram it gives only 20 percent as much power as gasoline; (c) the power of the engine is reduced from 20 to 40 percent depending upon the quality of the briquettes and the adjustment of the engine. Oak and birch are the most suitable kinds for use in gas generator installations.[47]

The Soviets have quite a variety of installations of varying size and degree of mechanization for producing briquettes. In general it can be said wood briquettes can be fairly easily produced by small saws and "choppers" at low cost; this is especially true in the timber industry, but briquettes can also be produced along with firewood, which is still an important fuel in the Soviet economy.[48] The machinery itself can be produced and repaired locally, and can even be powered by locomobiles operating on wood briquettes or other local fuels.

2. Charcoal

Some of its advantages are: (a) relatively high caloric content,

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45. BRONSHTEIN, p. 17.
46. BRONSHTEIN, pp. 17-29.
47. BRONSHTEIN, p. 17.
48. BRONSHTEIN, pp. 22-29.

[redacted]

(b) high reactive quality, (c) low ash and cinder content, (d) low moisture content,[49] and the fact that the generator installation weighs only about 40 percent as much as for wood briquettes.[50] Furthermore, charcoal will drive a vehicle almost twice as far as the same weight of wood briquettes. The content of volatile matter is also low.[51] On the other hand, charcoal is so brittle that transportation and storage losses are very high, up to about 15 percent by volume, and thus it is uneconomical to transport over long distances. This brittleness also entails losses in the gas generator and sharply reduces charcoal's relative advantage in the range of the vehicle. Lastly, charcoal absorbs moisture very rapidly when stored.[52]

3. Peat

Although peat has many suitable qualities as a fuel for gas generator engines, it has one extremely serious deficiency: the gas derived from burning peat has a very high content of sulphur, tars, dust, and volatile substances which both dirty and corrode the engine. Peat also has a very high moisture content. Much experimentation has been carried out, but so far the Soviets do not have a satisfactory filter to remove the objectionable impurities from the gas.[53] If such a filter can be developed the possibilities of utilizing peat for gas-generator driven vehicles seem to be very good, as substantial deposits of good-quality peat are found in the following regions: Archangel, Vologod, Tyumen, Omsk, Ivanov, Moscow, Smolensk, Gor'ki, and Yaroslavl'. Numerous other rajons have large deposits of peat with only a slightly lower quality.[54]

4. Anthracite

As a gas generator fuel anthracite has some very considerable advantages and disadvantages. Among the advantages are: (a) low content of volatile substances which permits the use of a very small filter, if the

49. BRONSHTEIN, p. 32.
50. BRONSHTEIN, p. 48.
51. BRONSHTEIN, p. 47.
52. BRONSHTEIN, p. 32, 48.
53. BRONSHTEIN, pp. 50-56.
54. BRONSHTEIN, p. 62.

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anthracite is of low sulphur content and if it has been washed; (b) low moisture content and no tendency to absorb it when in storage; (c) very high calorie content by weight,[55] and (d) very heavy by volume. The disadvantages, however, are quite serious. First of all, anthracite burns at very high temperatures, necessitating a heavy and expensive ceramic liner in the combustion chamber of the gas generator. Secondly, its tendency to clinker not only damages the ceramic liner but makes it difficult to start the generator after stopping. Maximum efficiency demands an admixture of steam; .3 to .4 kilogram of water should be expended for each kilogram of fuel, which consequently increases the over-all weight of the installation greatly.[56] Thus, at the present level of technology, the use of anthracite as a vehicular fuel is possible only under conditions of meticulous maintenance and a supply of anthracite of very high and uniform quality.[57]

Should it become technologically possible to use it efficiently, the supply and distribution of anthracite in the USSR would make it an excellent local fuel substitute for petrol. 1950 production is estimated at some 35,000,000 tons and, although production is concentrated in the Donbas, there are significant deposits in the Urals, the Kuznetsk Basin, and even in Primorskij Kraj.[58]

5. Bituminous Coal

Soft coal can be used as a gas generator fuel but has only a few desirable qualities: (a) high weight by volume, (b) low moisture content, and (c) high calorie content. On the debit side of the ledger, soft coal has several serious disadvantages: only two types of Soviet soft coal have an ash content low enough to make them practical, and these coals have a limited distribution. Soft coal tends to clinker and cake, damaging the ceramic liner. It has a low 'reactive quality' and a high sulphur and tar content. Finally the content of volatile substances varies but is usually too high.[59] Consequently, the prospects for using bituminous coal as a gas generator fuel are not too bright.

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The suitable types of soft coal are mined only in the Kuznetsk Basin, the Central Asiatic deposits, the Suchan and Bukarchichen deposits in the Primorskij area, and the Cheremkhov deposits near Lake Baikal. Thus, soft coal is in effect rather limited in geographic distribution.[60] However, since soft coal and anthracite are transported long distances for other uses, the transport of additional quantities for use as vehicular fuel might not necessarily be limited by the transportation problem as are many other hard fuels. On the other hand, the usual industrial demands for both these fuels are probably so heavy that the diversion of large amounts would not be practical, unless there is a drastic technological improvement in gas generators.

6. Lignite

It is very widely distributed, is produced at a very low cost, is fairly heavy by volume, and has a caloric content. In these respects it is much superior to wood briquettes. Its disadvantages are: high moisture, ash, tar, and sulphur contents; and fragility of fuel.[61] If the impurities were filtered out of the gas, lignite would make a good fuel. Some success in filtering has been achieved.[62]

One of the great advantages of lignite as a substitute fuel is its wide distribution, and the fact that the Soviets have spent, or are spending, considerable time and effort to develop and encourage the use of lignite in industry and power generation. Since lignite is a marginal or subsidized substitute for other coals this greatly increases the supply which could be made available for vehicles.

7. Cokes and Semi-Coke

Peat Coke

Peat coke possesses numerous qualities favorable for the purposes in question: high 'reactive quality', good weight by volume, reasonably high calorie content, and low ash and clinker content.[63] On the debit side, we have the fact that peat coke which is to be used in vehicle gas generators must have an ash content not in excess of 8-10 percent, which eliminates

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60. BRONSHTEIN, p. 72.
61. BRONSHTEIN, pp. 65-66.
62. BRONSHTEIN, p. 67.
63. BRONSHTEIN, p. 81.

most Soviet peats since it means that the ash content of the raw peat must not exceed 2-3 percent. Peat coke is very brittle and cannot be transported profitably over long distances. In general, its application is not feasible except in connection with the large-scale development of the peat coke and chemistry industry, in which case the coke would almost be a by-product.[64]

Local production of good quality peat coke can be carried on by small furnaces, and apparently at fairly low cost. One type of furnace will produce about 10 tons of peat coke from 32 tons of peat in 16 hours. However, a considerable amount of fuel is required to fire the furnace itself.[65] Alternative uses are neither so varied nor so crucial as to inhibit allocation of a large part of production as vehicular fuel.

8. Semi-Coke from Bituminous Coal and Lignite

This fuel has high 'reactive quality', does not absorb moisture in storage, is heavy by volume with good caloric content, giving a range of 200-250 kilometers for each filling. However, the gas has a considerable ash, dust, and deleterious chemical content. As in the case of other coals and cokes, a ceramic lining must be installed in the generator, and an admixture of steam to the generator is necessary.[66] Experiments with its use by various scientific institutes have given favorable results. One of the most important factors is insuring that the semi-coke is of very high and uniform quality; any slight deviation from the specifications will not only cause the vehicle to work badly but will also greatly increase wear.[67]

9. Metallurgical Coke

The "gazovoj" coke from the lignite gas-producing installations which were to have been constructed in the large industrial centers and in Central Asia during the fourth Five Year Plan might be of the necessary quality, but experiments along this line are still lacking. Research is to be carried out to discover methods for producing both a more efficient generator and better coke.[68]

64. BRONSHTEIN, pp. 80, 82.
65. BRONSHTEIN, p. 80.
66. BRONSHTEIN, pp. 83-84.
67. BRONSHTEIN, p. 87.
68. BRONSHTEIN, p. 90. In general, the Soviets have conducted no exhaustive experiments on utilization of coke on gas generators since before the war.

10. Chaff and Agricultural Wastes

When discussing the possibility of using this fuel in automobiles and tractors, Soviet writers display overtones of complete frustration. According to Soviet calculations there are about 102 million tons of chaff and other organic waste available each year, which, if it could be used, would greatly alleviate the fuel and transport problems of kolkhozes and Machine Tractor Stations which are far removed from a railhead. Briquetted chaff is an excellent fuel in every respect but two: first, at about 950° C the ash decomposes into a soggy mess which puts out the fire; secondly, the gas contains a great deal of dust which is deposited in the engine and in one test increased the wear on an SG-65 tractor by about 18 to 20 percent.[69] So far no satisfactory solution to these difficulties has been discovered, but at least three scientific institutes are working on the problem.[70]

11. Briquettes

Briquetting is one solution for hard fuels which are not quite satisfactory in their normal state, and has other advantages as well. Briquettes are a much more concentrated fuel with both a very high density and a very high caloric content. Undersized lumps and dust of various coals can be briquetted instead of wasted, blends which improve the final product can be produced, and the binder can also improve the quality of the fuel. Briquettes are more profitable to transport, there is much less waste, and they burn evenly in the gas generator. However, briquettes of various coals tend to contain too much ash for use in gas generators unless the coal is well washed before briquetting.[71]

Bituminous coal and dust from all the major producing basins can be briquetted. Suitable lignite deposits occur in Central Asia, the Ukraine and the Far East. The anthracite deposits of the Urals and Poltava are satisfactory as are both peat coke and semi-coke. Waste charcoal, which amounted to 250,000 tons per year in the Urals before the war, is especially suitable for briquetting.[72]

69. BRONSHTEIN, pp. 113-115.
70. BRONSHTEIN, p. 114.
71. BRONSHTEIN, pp. 93-94.
72. BRONSHTEIN, p. 93.

Charcoal itself is one of the best briquetted fuels; it can be briquetted with a variety of binders and thus becomes a highly transportable, concentrated, and stable fuel. Moisture absorption is greatly reduced as compared with lump charcoal.[73] Both peat coke and semi-coke make excellent briquettes if the ash content of the original peat is low enough.[74] Sawdust and wood wastes can be briquetted. Perhaps more important, these materials can be used to produce charcoal in small, cheap furnaces. Very large quantities of these waste products are available.[75]

There seems to be little or no evidence of extensive production of briquettes from these various fuels, with the exception of peat and coal. For these fuels the situation is somewhat different. Peat briquetting is believed to have proved much less economical than was hoped and is far behind plan. Coal briquetting, however, has proved eminently successful, is receiving more and more emphasis, and its volume is now probably much greater than was envisaged in the fourth Five Year Plan.

Granted better-quality fuel and a modicum of technological improvement in the generators themselves, briquetting coal, various cokes, and wood wastes should make possible the substitution of hard fuels for gasoline and diesel fuel on a very large scale.

12. Gases

Various kinds of gases are excellent substitutes for petrol fuel. The following is a list of those most suited to this purpose:[76].

Natural	extracted from natural gas fields, or concomitantly with oil at rate of 50 to 100 cubic meters per ton.
Petroleum	a) by-product of distillation refining; up to 50 percent of basic gasoline production of refineries depending upon, and increasing with, the octane rating of the gasoline.

73. BRONSHTEIN, pp. 103.
74. BRONSHTEIN, pp. 98-102.
75. BRONSHTEIN, pp. 110-113.
76. BRONSHTEIN, p. 135.

b) by-product of cracking, up to 10 percent of basic output;

c) by-product of pyrolitic cracking (cracking of low-grade by-products of distillation refining), up to 20 percent of basic production;

d) by-product of hydrogenation of coal, up to 20 percent of basic gas production.

Coke Gas — by-product of soft coal coke batteries, produced at rate of about 350 cubic meters per ton.

Sewage Gas — extracted from sewage by the canalization process; a city of 100,000 will produce 3,000 cubic meters per day, or enough for 60 to 70 trucks.[77]

Cooking Gas — produced from coals and lignite for cooking purposes.

These gases are divided into two groups according to the physical state in which they are used. All of the refining by-product gases are easily converted into liquid state when under pressure of from two to three atmospheres. Natural gas, coke gas, and the like are compressed in bottles at pressure of 200 to 350 atmospheres. Natural gases and those which occur with oil have a very high calorie content; one cubic meter of the lowest quality (from the Dashava Field) is equal to one liter of gasoline. For coking gas, sewage gas, and cooking gas the ratio is a little less than two cubic meters to one liter of gas.[78] The octane rating of these gases is extremely high, 100 for coke gas, 110 for cooking gas, and 120 or more for natural gas.[79] Consequently, while these gases can be burned in an ordinary engine with only a different type of carburetor with a loss of hp. of not more than 20 percent, in a higher-compression engine they will outperform gasoline. Liquefied refinery gas has about the same caloric content and octane rating as natural gas. Coke gas must be cleaned of certain impurities as must also gas extracted in conjunction with crude

77. SAMOL', G.I. and GOLDBLAT, I.I., "Gazoballonnye Avtomobili" (Gas Balloon Automobiles), Moscow 1951, p. 19.
78. BRONSHTEIN, pp. 144-146.
79. Ibid.

oil, but once this is done the wear on the engine is less than with gasoline. Furthermore, the addition of a small amount of natural gas with a high methane content will produce a much richer gas, almost to the point where one cubic meter equals one liter of gasoline.

The principal drawback to the use of these compressed gases is the weight of the metal flask. Thus the ZIS-5 truck, normally rated at 3 tons capacity, is reduced to 2.5 tons capacity when fitted for operation on compressed gas while the 1 1/2 ton GAZ-44 is reduced to 1.1 ton capacity. Refinery by-product gases are liquefied under such low pressure (2 or 3 atmospheres) that the weight of the container is not a serious detriment. This gas can also be transported in bulk in tank cars and trucks.

The possibilities for the utilization of compressed and liquefied gases as vehicular fuel seem to be very good. Exploited natural gas fields exist at Dashava near Kiev, at Saratov near Kuibyshev, in Dagestan, and in the Groznyi-Baku area. Furthermore, the Saratov-Moscow pipeline makes possible the use of natural gas to enrich locally produced cooking, coke, and sewage gases. As has been noted in the Introduction, a good start toward large-scale use of natural gas has been made in the Ukraine.

Two of the chief limiting factors in the use of compressed gases are the weight of the flasks and the special compressor stations which must be erected. Not only do the flasks reduce the load capacity of the vehicle, but they must be made of either high-grade steel or a special aluminum alloy with steel reinforcing. Since each vehicle must have at least two sets, a considerable amount of high-grade steel and/or aluminum alloy is required. However, the use of these alloys would only reduce the load capacity by 250 to 300 kilograms instead of about 500 with the older-type bottles.[80]

A considerable investment is required to construct compressor stations. A "typical" compressor station working two shifts, 300 days a year, will compress about 1,700,000 cubic meters of gas. If this were natural gas it would be the equivalent of 1300 tons of gasoline, if

80. BRONSHTEIN, pp. 150-151.

coke gas the equivalent of about 650 tons, or enough for 80 or 40 trucks respectively.[81] Such a station is powered by two 100-hp. electric motors.[82] Expressed in rubles, the equivalent of 1 liter of gasoline in compressed natural gas is 35 kopecks, in coke gas 70 kopecks; gasoline is listed at 75 kopecks per liter.[83]

81. SAMOL, pp. 161-162.
82. SAMOL, pp. 177-178.
83. SAMOL, pp. 161-162.